Climate Change and the Predictability of Intraseasonal Temperature Variability

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1 NOAA Climate Prediction Center (CPC)
2 Innovim, LLC

NOAA-ESRL retrospective forecasts

Next generation NOAA GEFS reforecasts created by ESRL:

- Current operational NCEP Global Ensemble Forecast System (GEFS) as of February 2012
- T254L42 (about ½ degree grid spacing) in week 1 and T190L42 (about ¾-degree) in week 2
- 0Z cycle 10 perturbation ensemble members + control
  - 4 cycles x 21 members per day in real-time GEFS
- 1985-2011
- Initial conditions from Climate Forecast System Reanalysis (CFSR) (2011 and real-time using GDAS)
- Data available by ftp from NOAA and DOE
- http://esrl.noaa.gov/psd/forecasts/reforecast2/

Comparison to the NCEP Climate Forecast System (CFSv2):

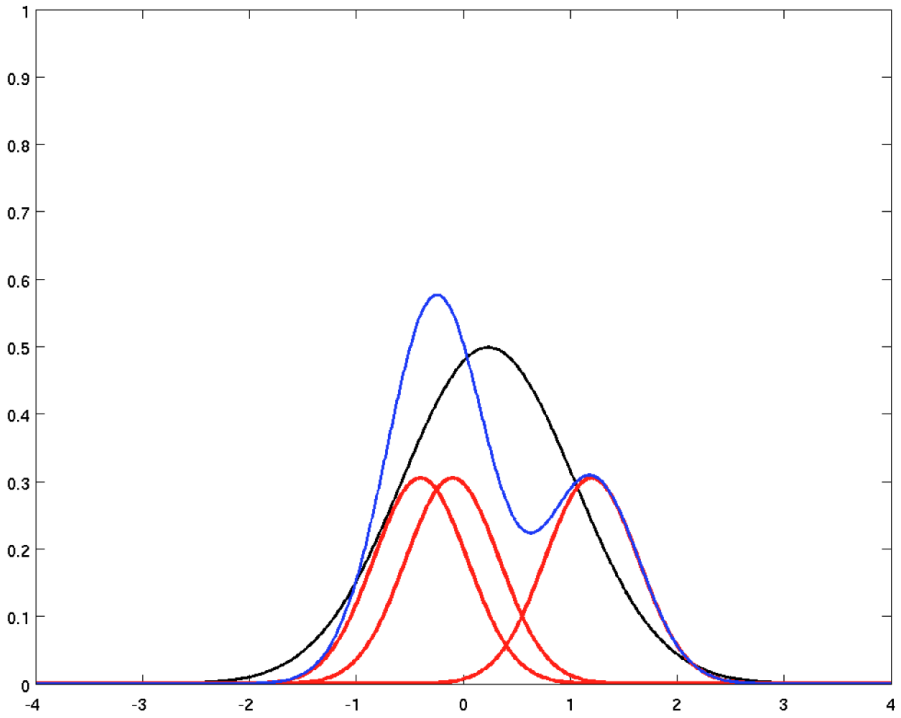
- T126L64
- 4 members x 4 cycles per day to 45-days lead in real time
- 4 members per day reforecasts
- 1999-2011

Benefits of using retrospective forecasts

- Greater number of independent cases needed for forecast-observation comparison for intraseasonal variability
- **Larger training data-set allows for a more refined calibration of uncertainty (spread) and more reliable forecasts**
- Bias estimate from recent forecast-observation pairs is always lagged from real-time forecasts and associated with recent climate regime
  - Leads to systematic errors related to the seasonal cycle and regime changes
  - Reforecast bias estimates can be centered on target dates and averaged for multiple years / regime changes

Representing Probability Density Functions based on linear regression:

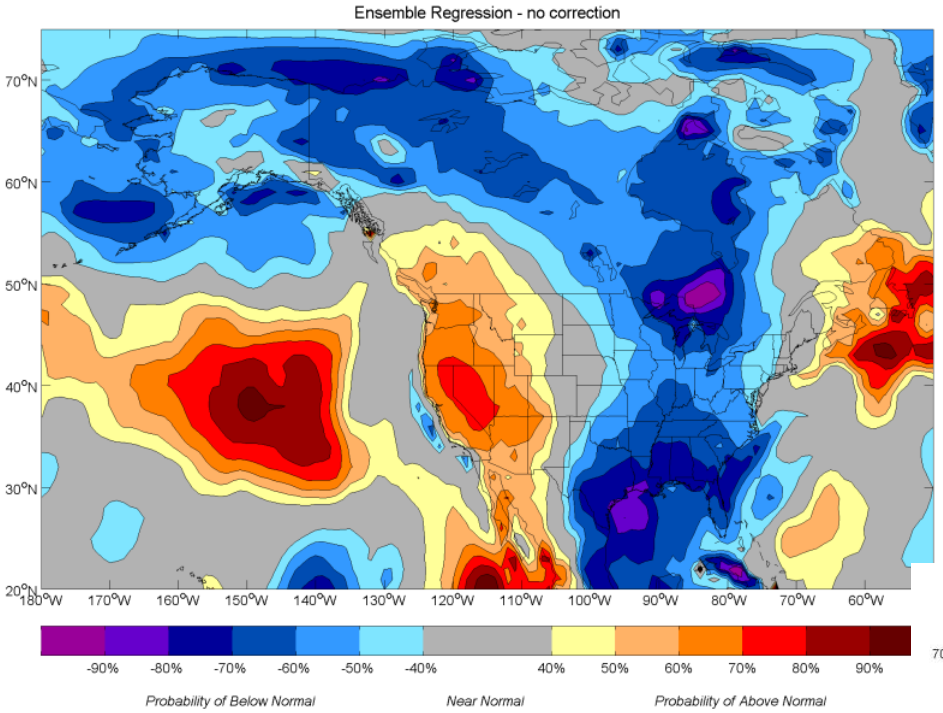
$$\sigma^2_{\text{Error variance}} = \sigma^2_{\text{Observed}} (1 - R^2)$$



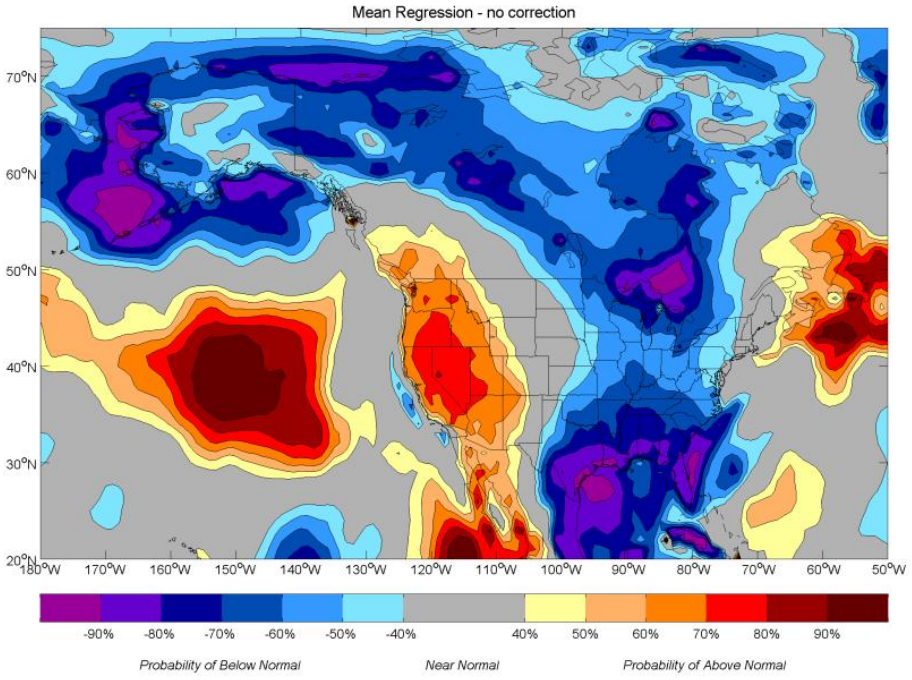
- Individual ensemble member forecasts
- Summed ensemble regression PDF
- Regression of ensemble mean

Uncertainty depends on R which depends on the model-observation covariance, which ultimately depends on the climatological mean of the model and observations

Ensemble Regression



Regression of ensemble mean

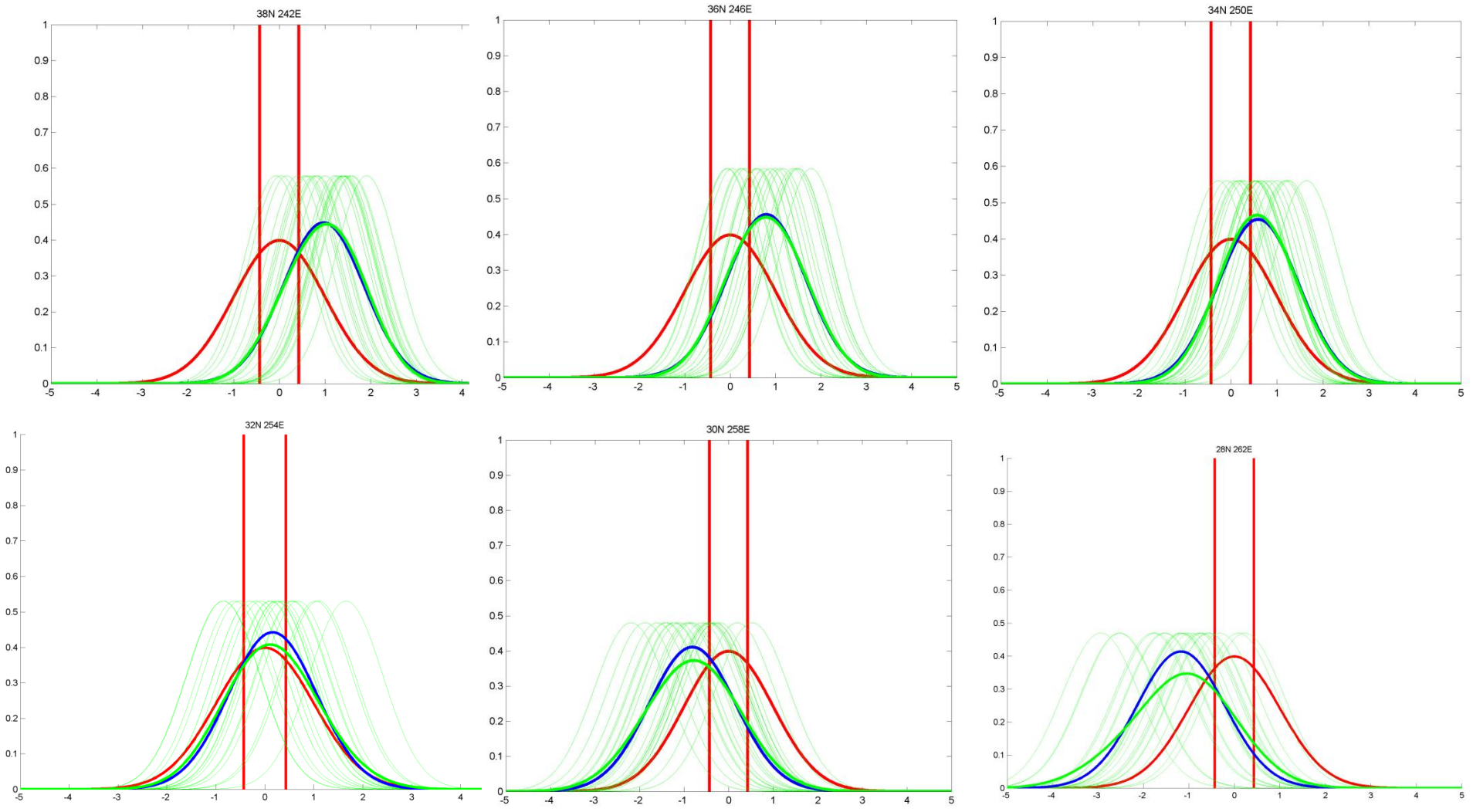


Using Regression corrects…

- Mean bias by removing model climatology
- Corrects the variance of the ensemble mean
  - $\sigma^2_{\text{Ensemble members}} = Es\text{^}2 + \sigma^2_{\text{Ensembl Mean}}$
- Damps forecasts towards observed climatology by skill
- Estimation of the error of the forecast used to correct the uncertainty described by the ensemble spread, to produces reliable probability forecasts

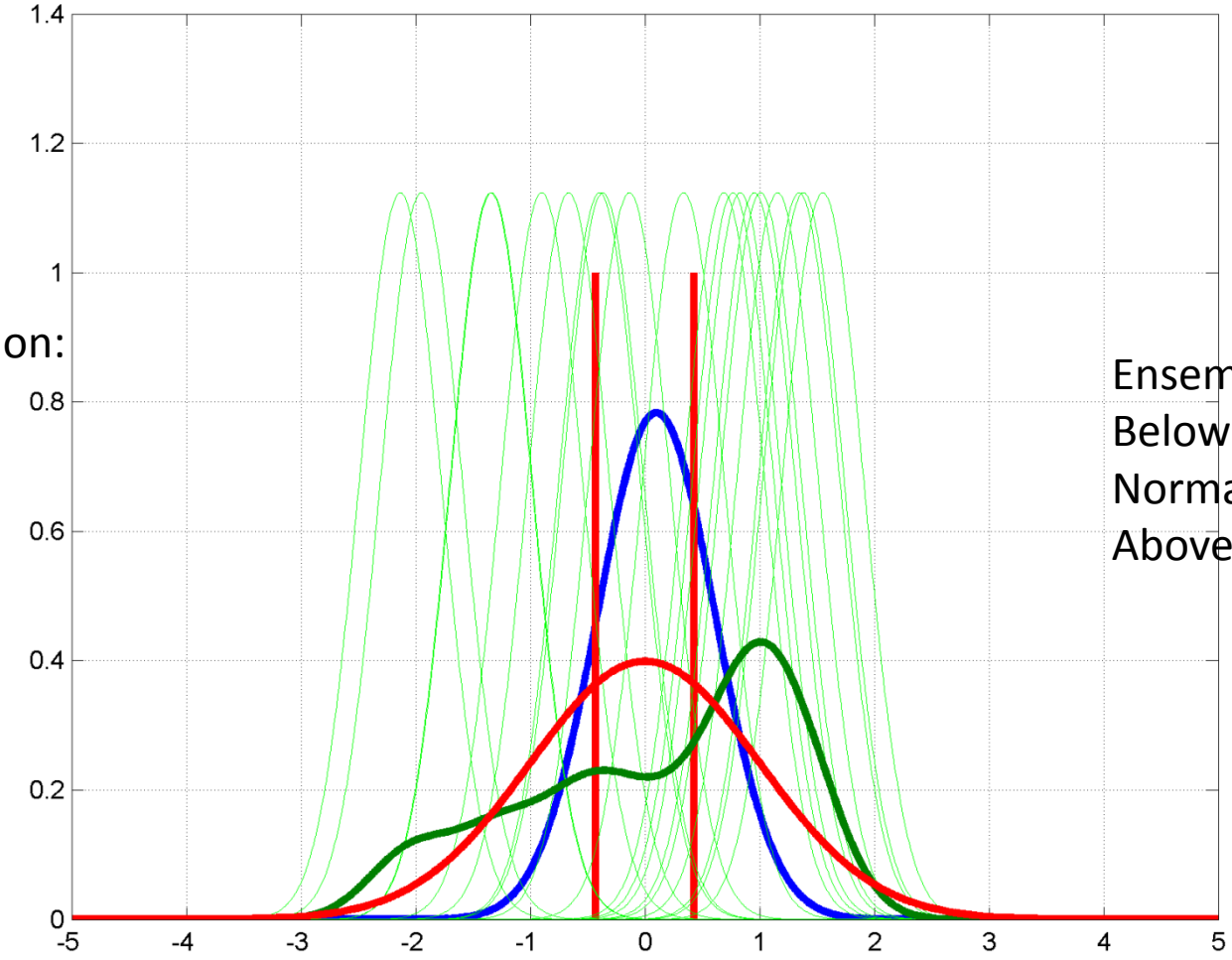
$$\sigma^2_{\text{Error variance}} = \sigma^2_{\text{Observed}} (1 - R^2)$$

Shifts in the probability distribution represented by ensemble members



A forecast with unusually large spread

Mean Regression:
Below: 15%
Normal: 60%
Above: 25%



Ensemble Regression:
Below: 32%
Normal: 20%
Above: 48%

Using retrospective forecasts

- Determining the systematic error generally assumes the statistics are stationary over reforecast data set.

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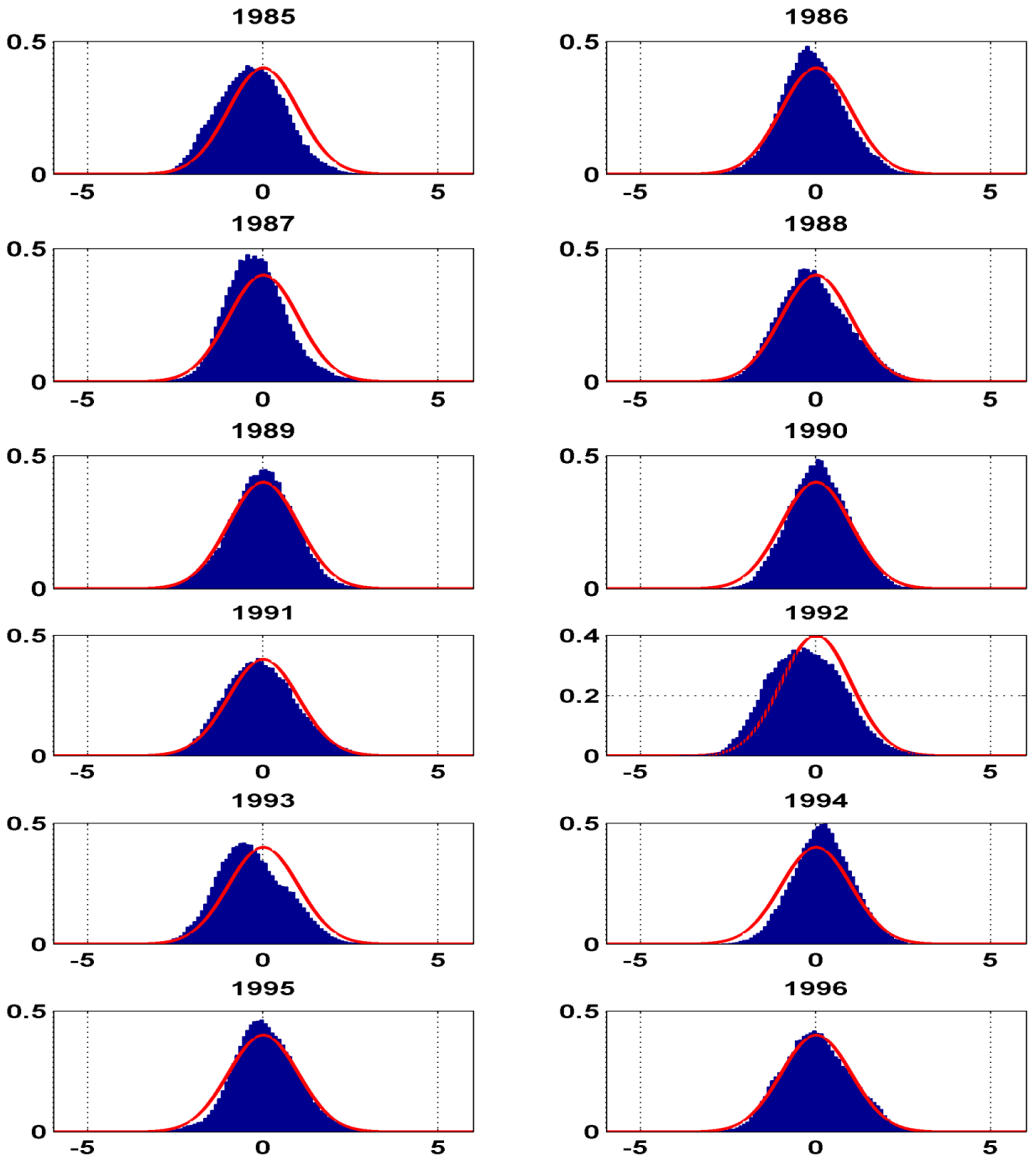
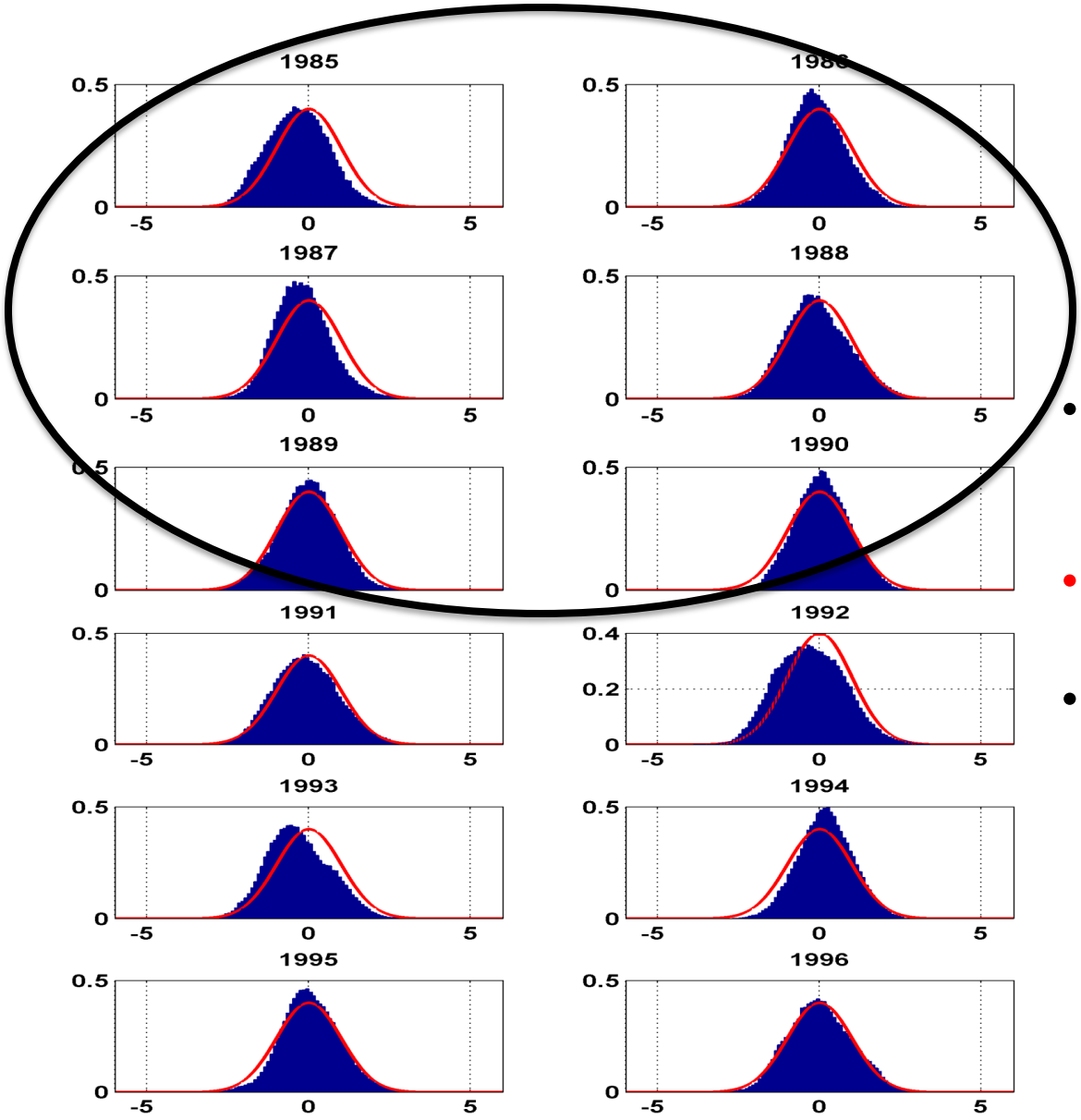
- Are the statistics stationary in a changing climate?



- Weekly mean forecast temperatures over the U.S. by year
- 25-year climatology in red
- PDF shifting each year



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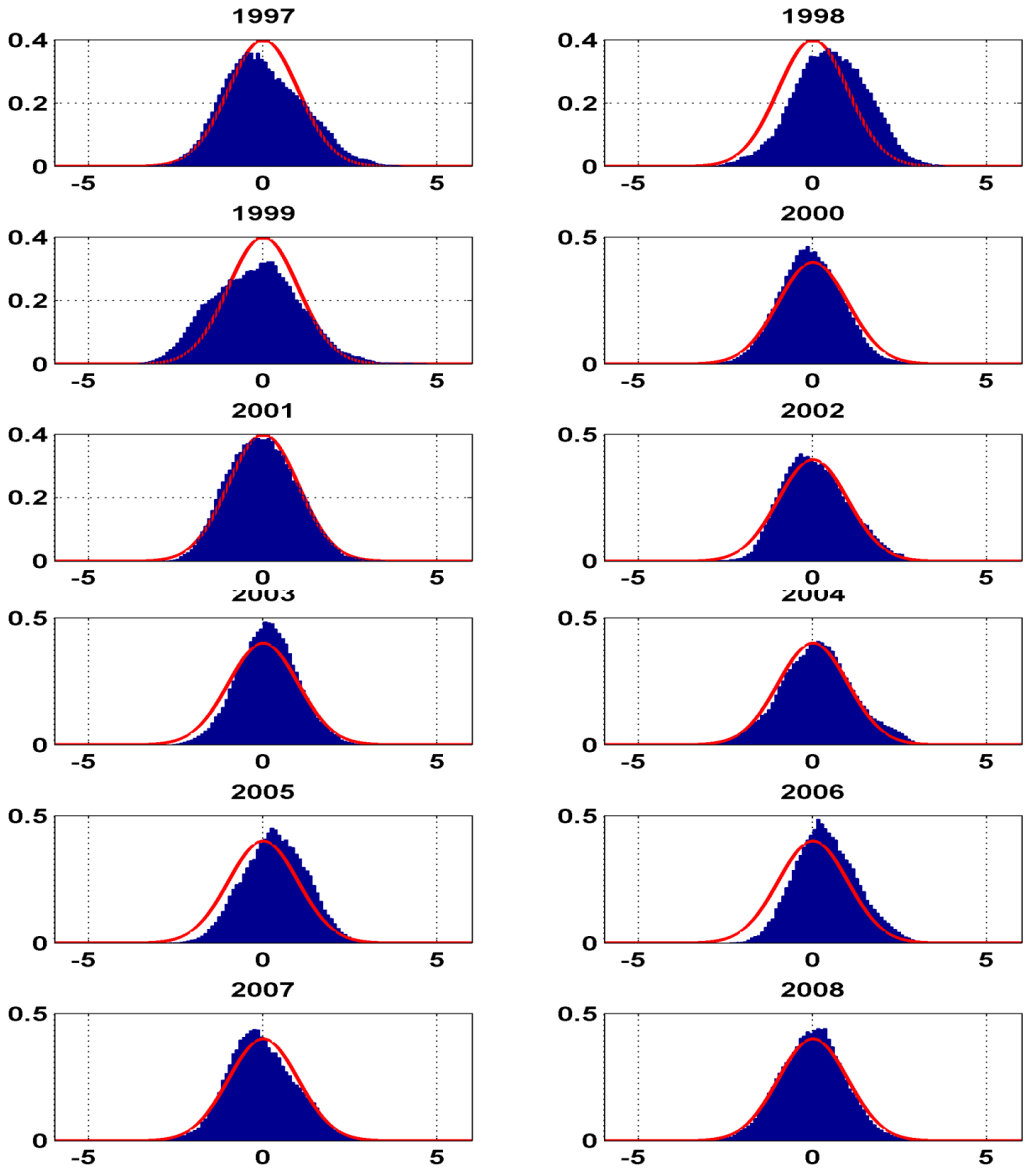
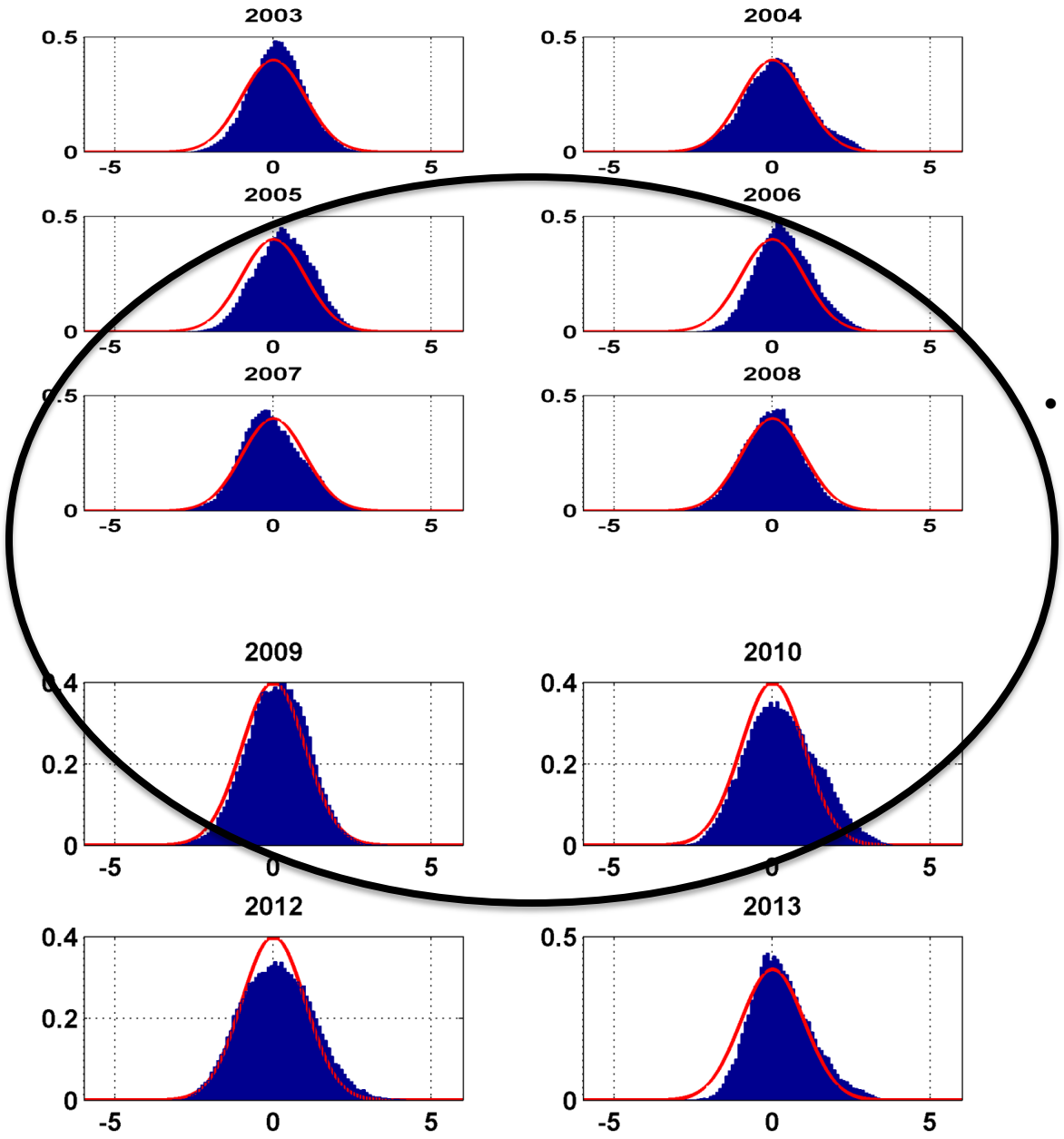
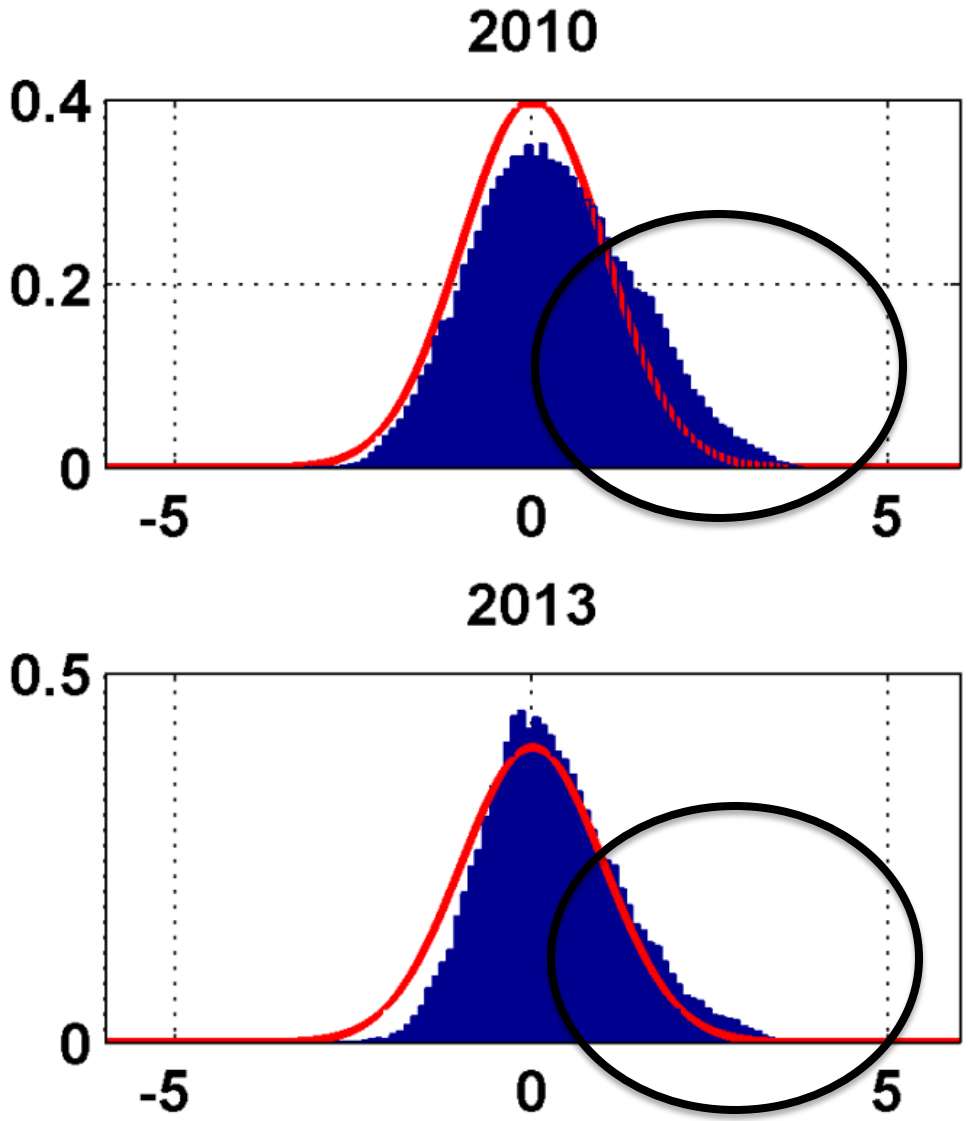


- Multi-decadal temperature trends apparent in intraseasonal forecasts



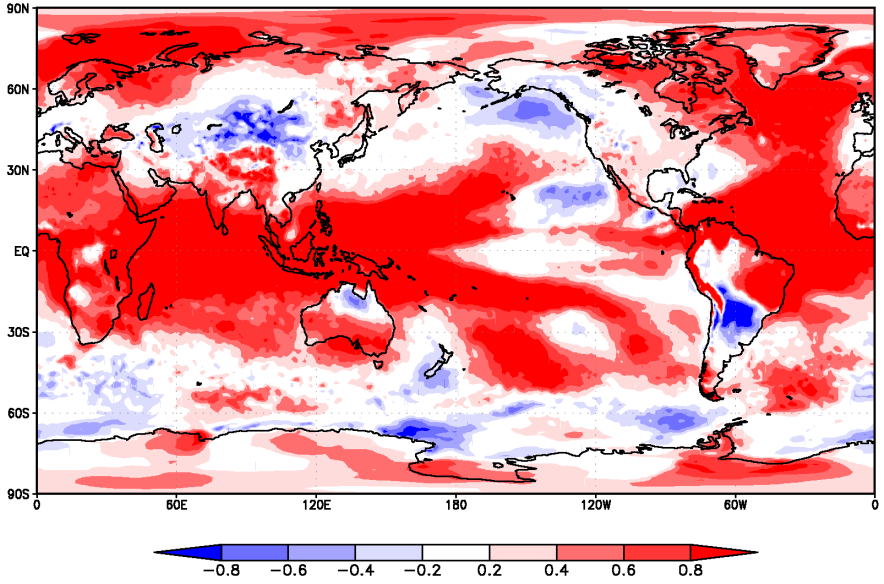
- Shift towards warmer temperatures in more recent years



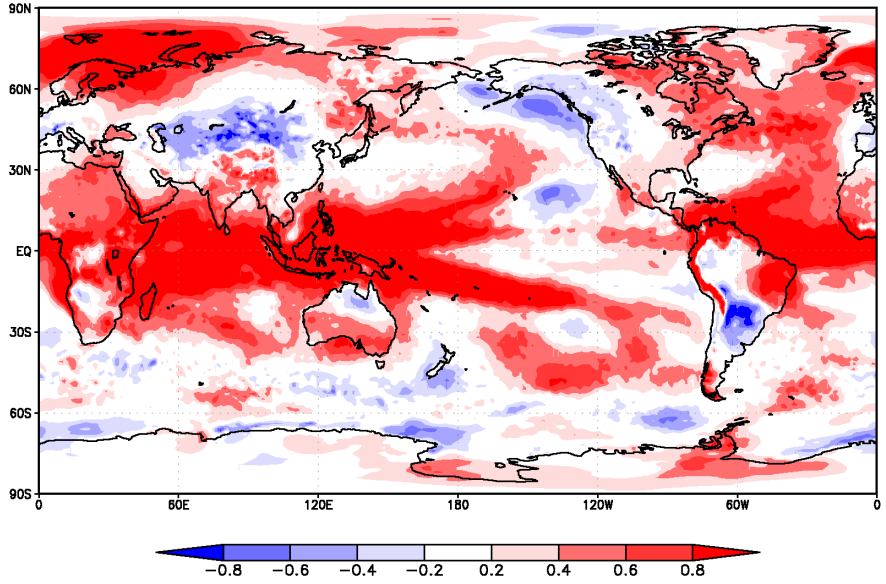
- Increase in the frequency of extremes

25-year (1985/6 to 2009/10) linear trend of 2-meter temperatures in model initialization December-January

Standardized linear temperature change



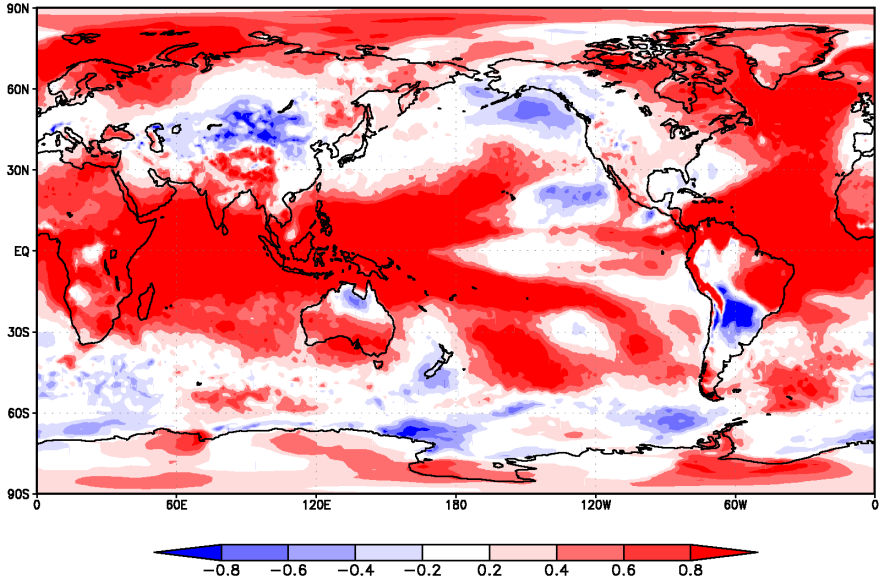
2005-2010 minus 1985-1990



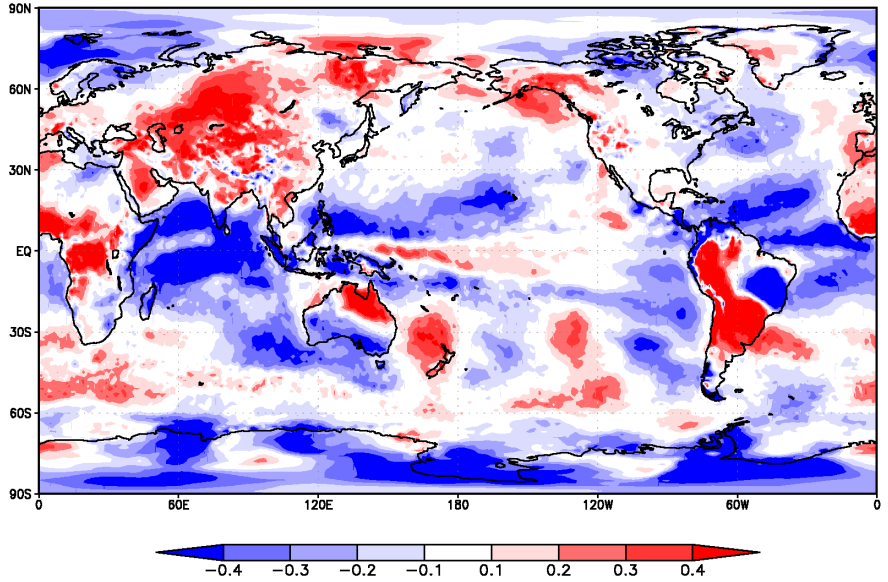
- More areas are similar than not
- Trend nearly linear

Model bias (right) is changing with changing background climate state (Dec-Jan)

Standardized linear temperature change



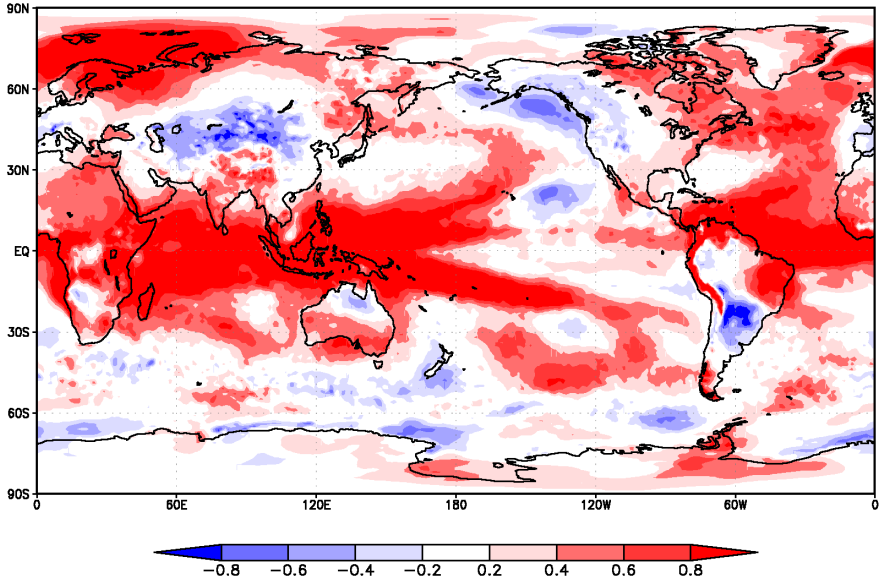
Standardized linear trend of ensemble model mean bias



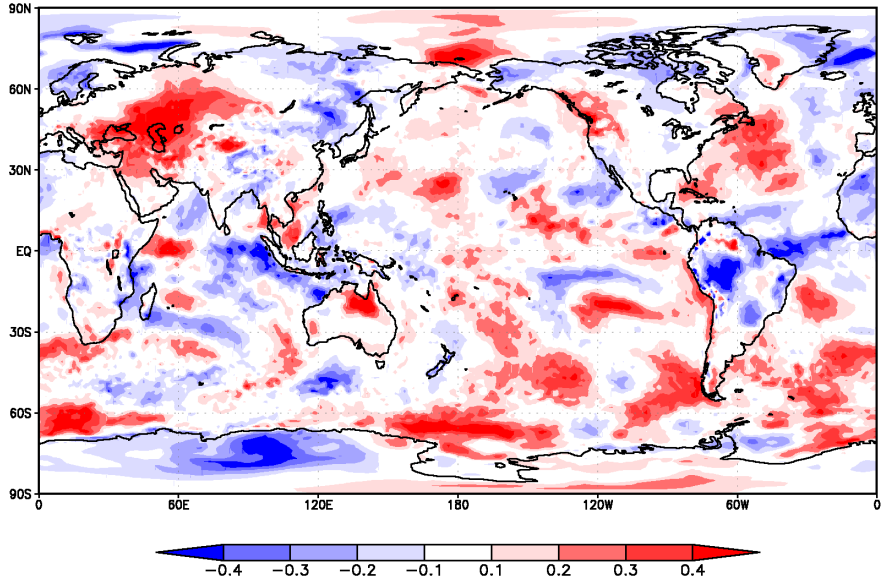
- Growing cold bias where trend is greatest
- Using the mean 25-year model climatology for bias-correction introduces error

Changing variance of observations (right) with changing background climate state (Dec-Jan)

2005-2010 mean
minus 1985-1990 mean



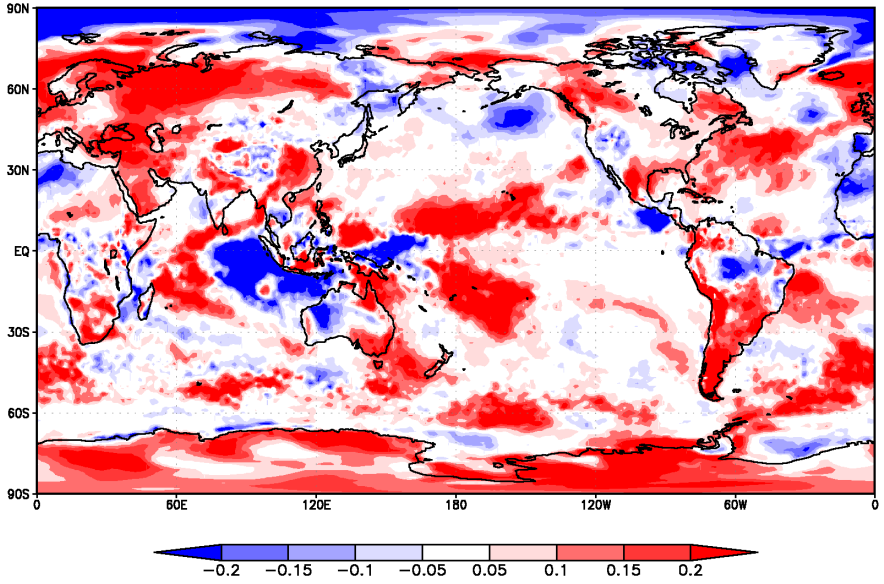
2005-2010 variance
minus 1985-1990 variance



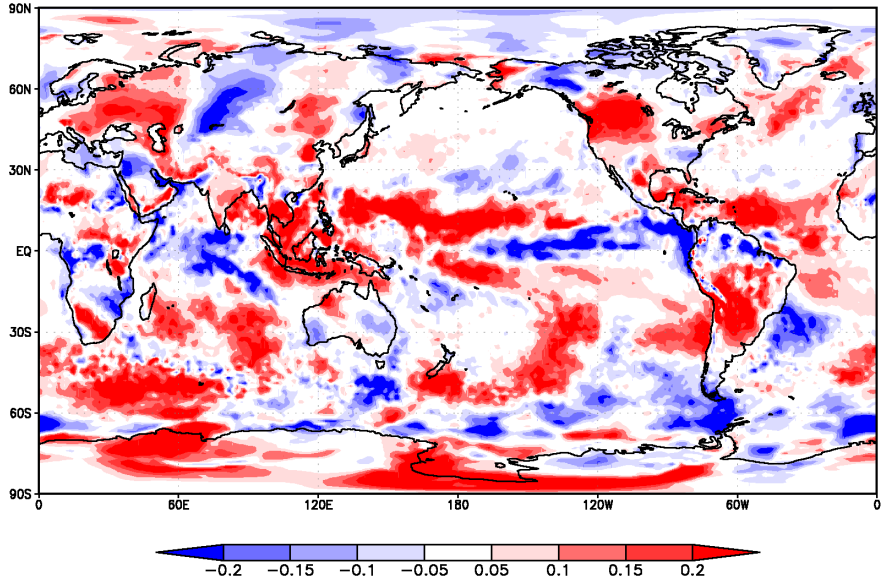
- Variance relative to changing mean state
- Systematic changes in some regions coincide with changes in mean

Changing correlation between forecasts and observations (left) with changing background climate state

December-January



June-July



- Predictability appears non-stationary in some regions ($\Delta R > .2$)
- 2005-2010 forecast-observation R minus 1985-1990 forecast R
- E.g. Increasing predictability of Western Pacific

Conclusions

- Temperature trend is significant fraction of intraseasonal variance and of signal
- The systematic bias between the ensemble mean and observations is also changing as the mean climate state changes.
- Regionally the variance appears to also change significantly with climate change
- Using regression for calibration of ensemble forecasts, regression coefficients should change with time
- Possible implied changes to the predictability of intraseasonal variability in a changing background state